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(54) Abstract Title
Electrically controlling multiple downhole devices

(57) A production well control system 10 for electrically controlling multiple downhole devices (41, figure 2) individually or as a group comprises a surface control unit 12, a downhole control module 30 and multiple interface units 40, 50 etc. The operator inputs a command or request to the surface control unit which is passed to a power and communication system 14. The power and communication system generates a command signal of sufficiently high voltage to be sent downhole to the control module 30 which interprets and reformats the signal. The control module is connected to the multiple interface units, each of which is associated with a valve 41. Each interface unit is programmed to respond to a certain signal, energising its particular valve and transmitting data back to the control module 30. Alternatively, the valves are automatically actuated by the sensing of a downhole parameter such as temperature or pressure.

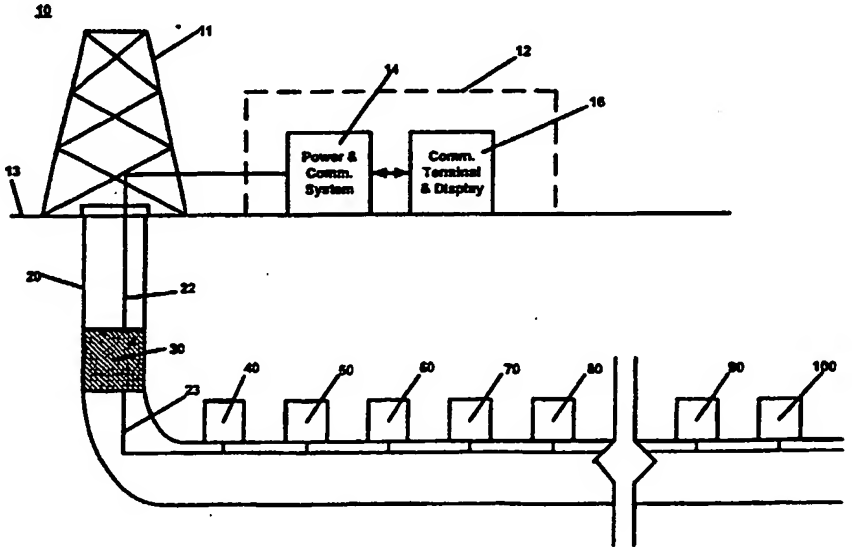

Figure 1

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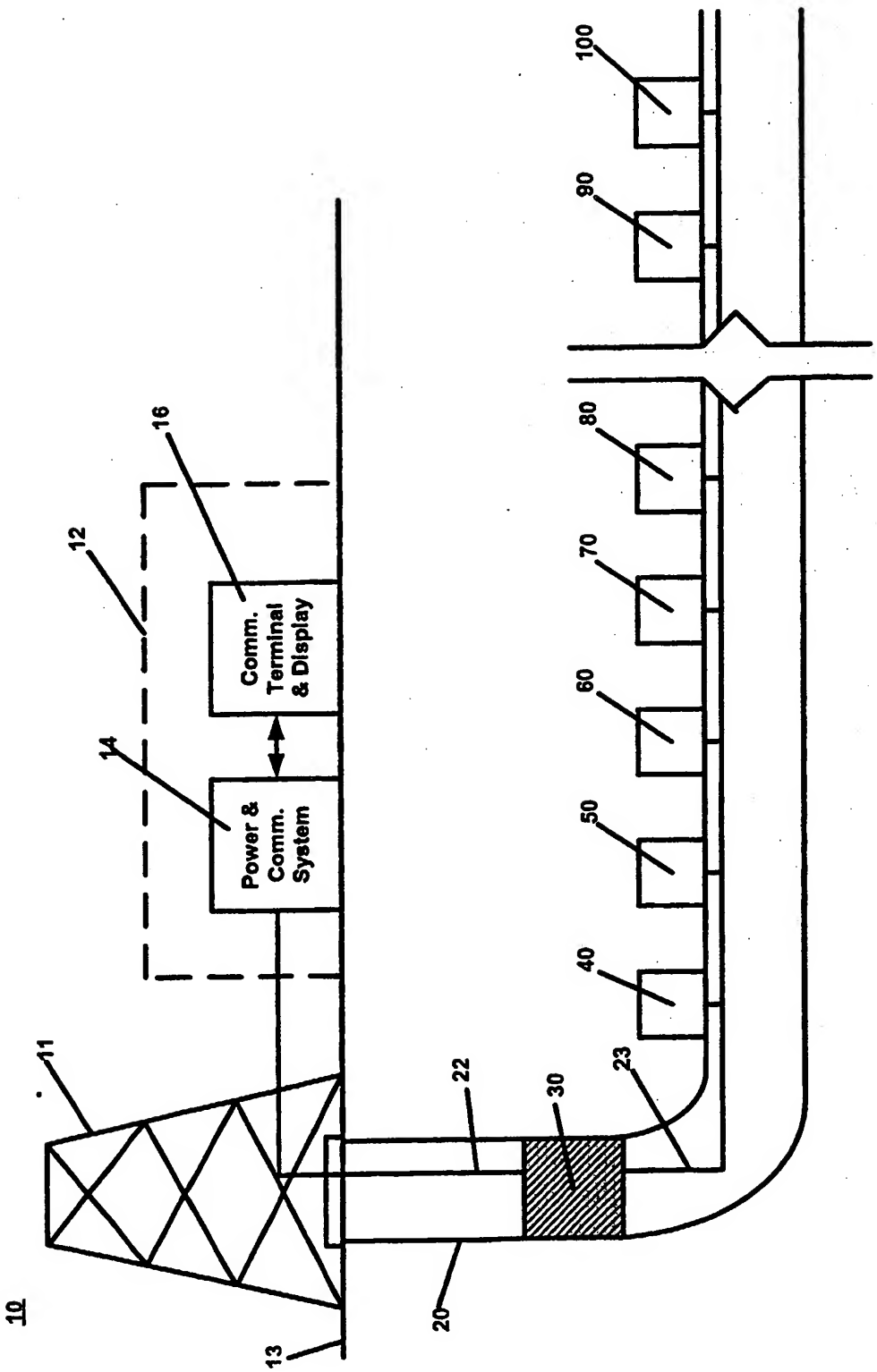
10
11
12
13
14
16
Comm. Terminal & Display
Power & Comm. System
20
22
23
30
40
50
60
70
80
90
100

Figure 1

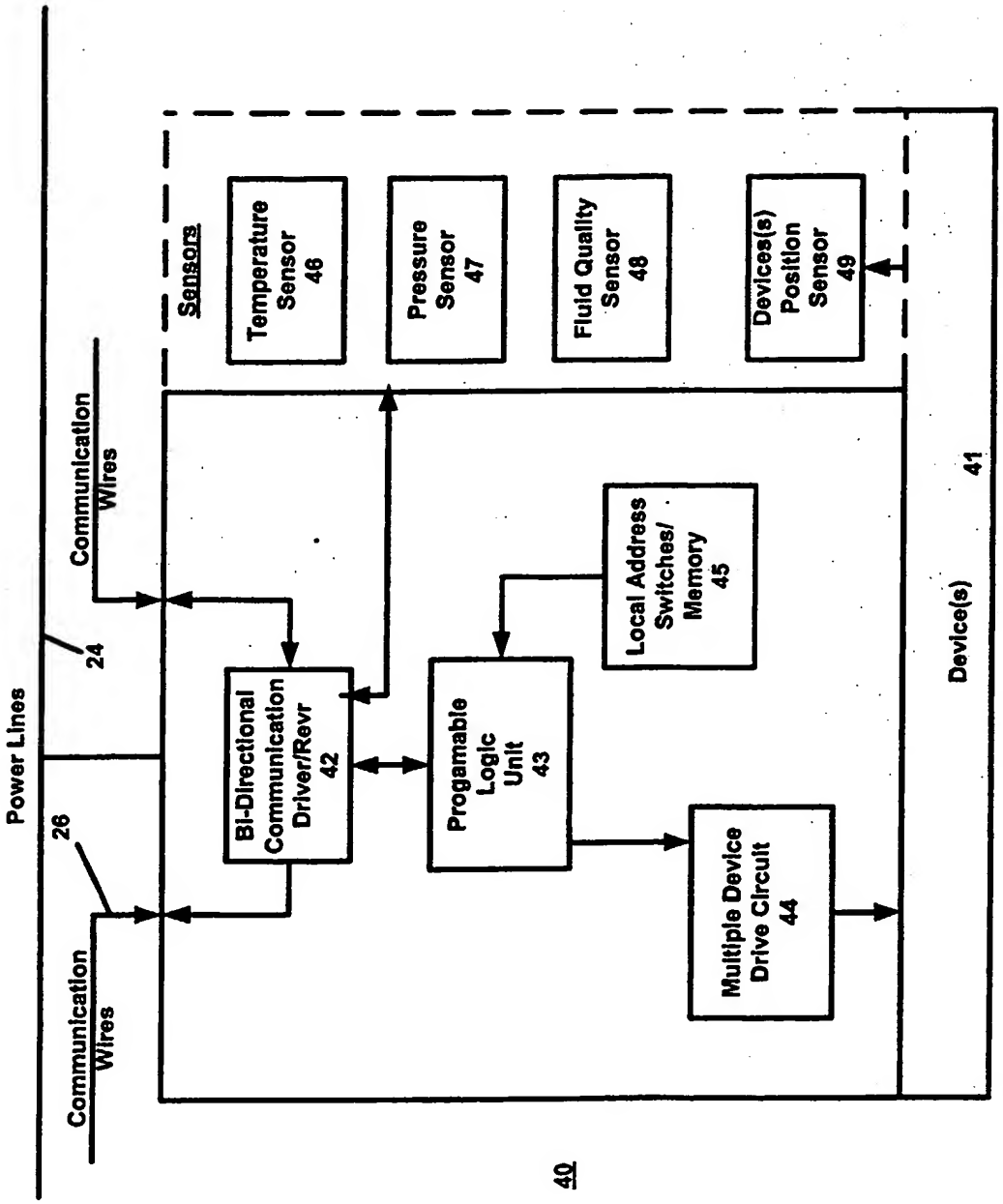
Power Lines
24
26
Communication Wires
Communication Wires
Sensors
Temperature Sensor 46
Pressure Sensor 47
Fluid Quality Sensor 48
Devices(s) Position Sensor 49
Bi-Directional Communication Driver/Revr 42
Progamable Logic Unit 43
Local Address Switches/ Memory 45
Multiple Device Drive Circuit 44
Device(s)
41
40

Figure 2

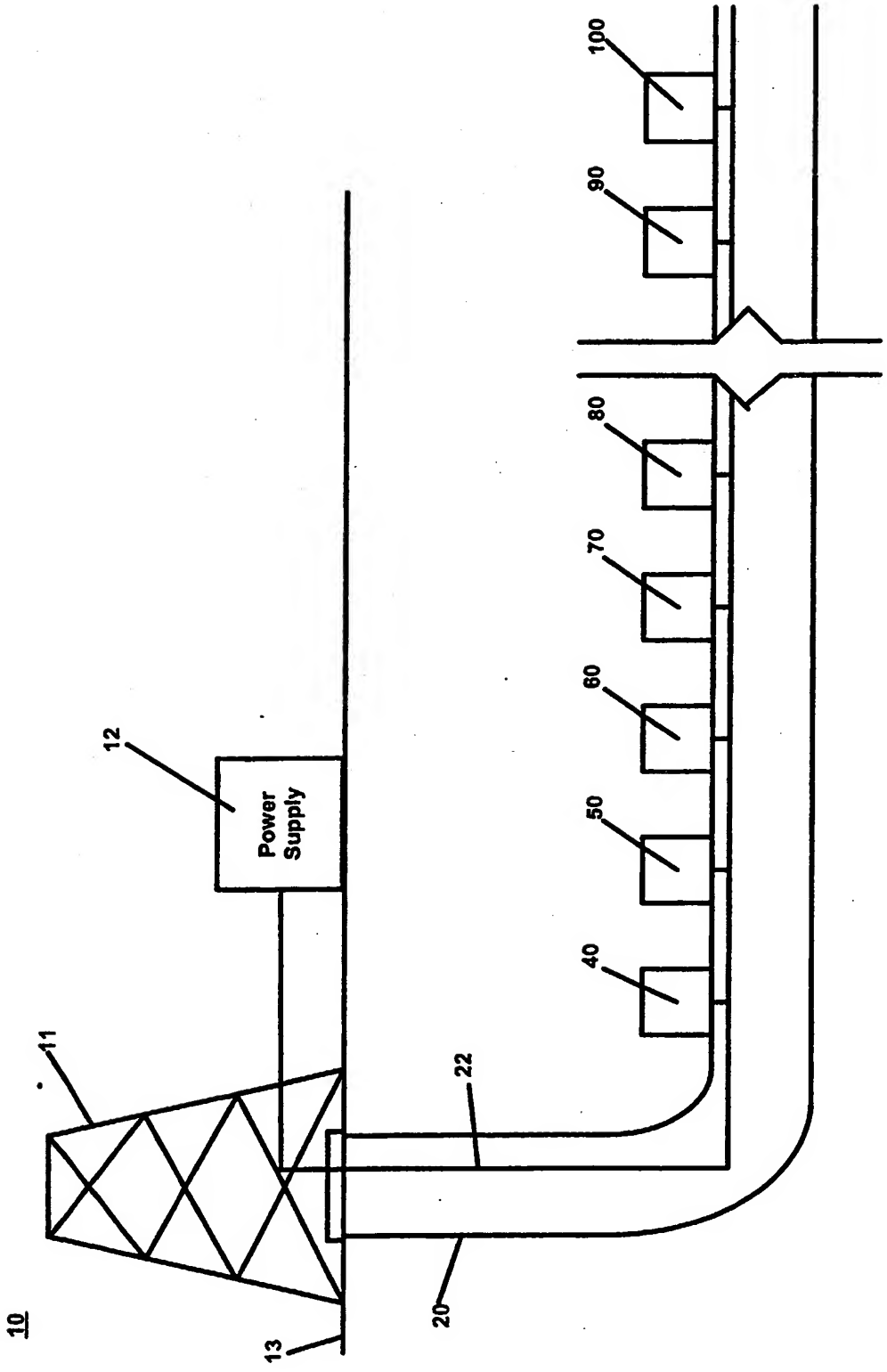

Figure 3

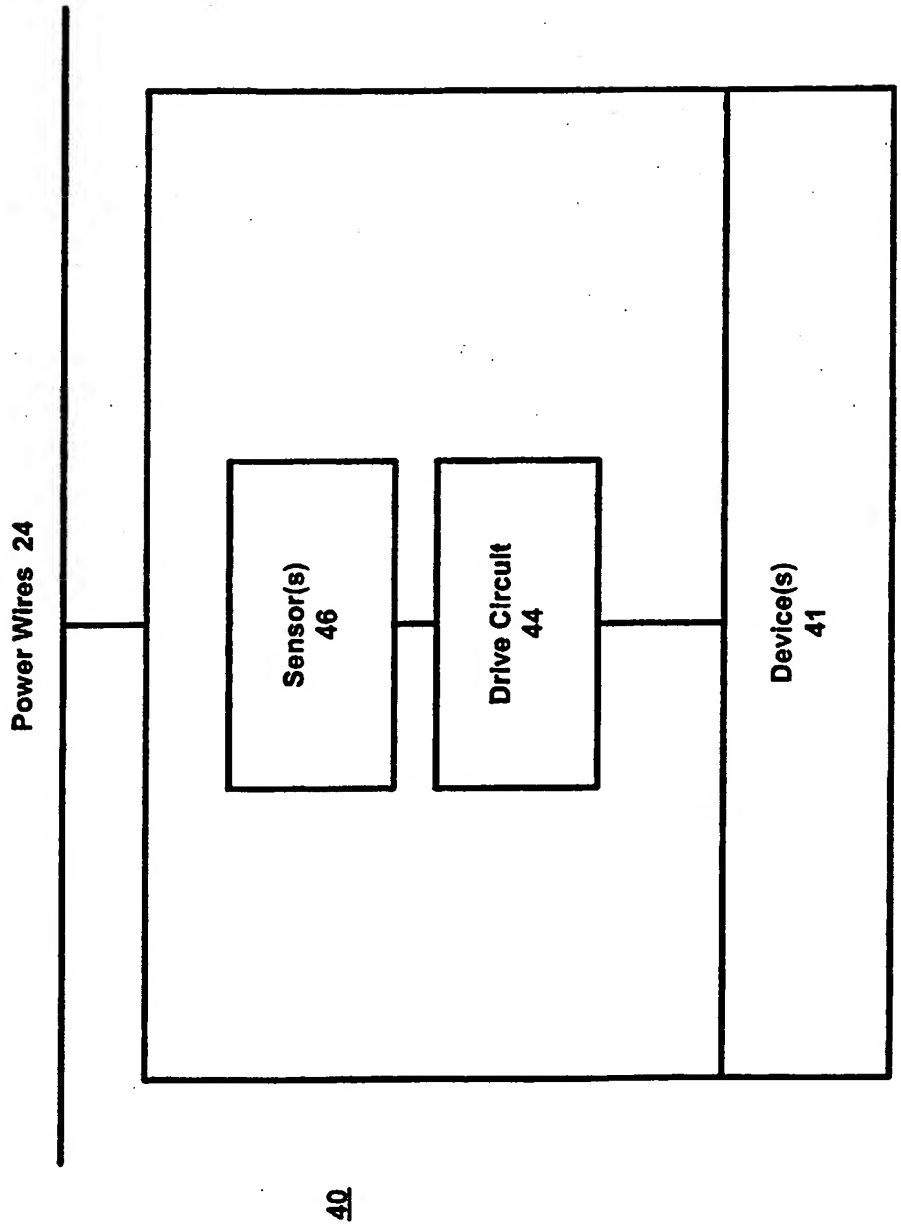

Figure 4

APPARATUS AND METHOD FOR ELECTRICALLY CONTROLLING MULTIPLE DOWNHOLE DEVICES

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates generally to oilfield well operations and more particularly to an apparatus and method for electrically controlling multiple downhole devices.

Description of the Related Art

The control of oil and gas production wells constitutes an on-going concern of the petroleum industry due, in part, to the enormous monetary expense involved as well as the risks associated with environmental and safety issues.

It will be appreciated that relatively simple, timed intermittent operation of valves and the like are often not adequate to control either outflow from the well or injection to the well so as to optimize well production. As a consequence, sophisticated computerized controllers have been positioned at the surface of production wells for control of downhole devices such as motor valves.

Surface controllers are often hardwired to downhole sensors which transmit information to the surface such as pressure, temperature and flow. This data is then processed at the surface by the computerized control system.

While it is well recognized that petroleum production wells will have increased production efficiencies and lower operating costs if surface computer based controllers and downhole microprocessor controllers (actuated by external or surface signals) are utilized, current control systems nevertheless suffer from drawbacks and disadvantages. For example, reliability of surface to downhole signal integrity in a surface control system wherein a downhole microprocessor is actuated by a surface signal is a major concern. It will be appreciated that should the surface signal be in any way compromised on its way downhole, then important operations will not take place as needed.

Prior art surface control systems generally require a surface platform at each well for supporting the control electronics and associated equipment. However, in many instances, the well operator would rather forego building and maintaining a costly platform. Thus, a problem is encountered in that use of present surface controllers require the presence of a location for the control system, namely the platform.

Disadvantages of present production well control systems involves the extremely high cost associated with implementing changes in well control and related workover operations. Presently, if a problem is detected at the well, the customer is required to send a rig to the wellsite at an

extremely high cost (e.g., 5 million dollars for 30 days offshore work). The well must then be shut in during the workover causing a large loss in revenues (e.g., 1.5 million dollars for a 30 day period). Associated with these high costs are the relatively high risks of adverse environmental impact due to spills and other accidents as well as potential liability of personnel at the rig site. Of course, these risks can lead to even further costs. Because of the high costs and risks involved, in general, a customer may delay important and necessary workover of a single well until other wells in that area encounter problems. This delay may cause the production of the well to decrease or be shut in until the rig is brought in.

SUMMARY OF THE INVENTION

The present invention provides a production well control system for controlling multiple downhole devices, preferably, but not limited to, valves, separated by thousands of meters. This system allows for economic, reliable and reversible means of controlling a plurality of downhole devices.

In accordance with a first embodiment of the present invention, a surface control unit, downhole control module and interface unit are provided for selectively controlling downhole devices. An important feature of this invention is the ability to access individually, or as a group, multiple devices (e.g., valves) arranged in a distributed scheme. The number of downhole devices that can be

controlled by this apparatus is only limited by the data address sizes, the power delivered and the power consumed. Additionally, the apparatus is inherently more reliable with each downhole device electrically coupled to an interface unit having a unique, stored address which must correspond to a surface transmitted address before actuation of the downhole device.

In accordance with a second embodiment of the present invention, comprising downhole sensors, downhole devices and a downhole control module whereby the control module automatically controls the downhole devices based upon a sensed downhole parameter or event. Therefore, using downhole sensors, the downhole control module will monitor actual downhole parameters (e.g., pressure, temperature, flow) and automatically execute control instructions to activate the downhole devices when parameters reach a preset limit or are outside of an optimum operating range.

In contrast to the first embodiment, well control systems which consist of a control module located wholly at the surface and a downhole computer system which requires an external initiation signal (as well as a surface control system), the downhole well production control system in the second embodiment automatically operates based on downhole conditions sensed in real time without the need for a surface or external signal. This important feature constitutes a significant advance in the field of

production well control. Additional advantages of this system include elimination of the need for a surface platform and an even more reliable communication system since no surface to downhole actuation signal is required and the associated risk that such an actuation signal will be compromised is therefore rendered moot.

A power source provides energy to the downhole control unit in both embodiments described below. Power for the power source can be generated, preferably, at the surface or in the wellbore (e.g., by a turbine generator) or supplied by energy storage devices such as batteries (or a combination of one or more power sources). The power source provides electrical voltage and current to the downhole electronics, electromechanical devices and sensors in the wellbore.

Examples of the more important features of the invention thus have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

For detailed understanding of the present invention, references should be made to the following detailed

description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals and wherein:

FIGURE 1 is a schematic diagram of a production system that employs the apparatus of the present invention;

FIGURE 2 is a block diagram showing an interface unit in accordance with the present invention;

FIGURE 3 is a schematic diagram of the production system that employs an alternative embodiment of the present invention; and

FIGURE 4 is a block diagram showing a control unit of the alternative embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 is a schematic diagram of a production system **10**, including a conventional derrick **11**. A surface control unit **12** at the surface allows an operator to generate a command/request to be executed downhole. The operator may request downhole data or actuate one or more downhole devices by inputting a command into a communication terminal and display **16**. The command is communicated by wire or wireless to a power and communication system **14**.

The power and communication system **14** generates a command sequence and sufficient voltage to drive the selected downhole device. Specifically, the power and communication system **14** encodes the operator's command as a command signal using a synchronized communication technique, preferably Manchester data encoding. The power and communication system **14** also generates a sufficiently high voltage to ensure that the command signal and activation voltage arrive at a downhole control module **30**. The command signal and activation voltage are transmitted from the power and communication system **14** to the downhole control module **30** via twisted pair wiring housed in armored and shielded lines **22** extending downward from the surface **13** into the wellbore **20**.

Upon receipt of the command signal and activation voltage, the downhole control module **30** interprets and reformats the command signal before transmitting a command serial data package and the activation voltage via armored and shielded lines **23**, comprising a bi-directional four wire communication path comprising two wires for communicating power, one wire for communicating a clock pulse and one wire for communicating data. Power lines **24** and communication lines (e.g., clock pulse wire and data wire) **26**, shown in **Figure 2**, are connected to an interface unit **40** which is electrically coupled to at least one downhole device **41**, preferably, but not limited to, a valve. Returning to **Figure 1**, the downhole control module **30** may transmit the command signal and activation voltage to multiple interface

units **40**, **50**, **60**, **70**, **80**, **90** and **100** in a distributed control scheme.

As shown in **Figure 2**, the interface unit **40**, comprises a bi-directional communication transmitter and receiver or transceiver **42** which receives and transmits the data and clock pulse from communication line **26**. The receiver/transmitter or transceiver **42** allows data to travel bi-directionally through the armored and shielded wire **23** in a half duplex manner. A programable logic unit **43**, within the interface unit **40**, decodes the address and clock and compares the transmitted address in the command serial stream to the local address stored in memory **45**. The local address is either electrically programmed before or after the interface unit **40** is placed downhole or hardwired into the interface unit **40** prior to placement downhole.

If the transmitted address in the command serial stream and the stored address in the interface unit **40** are equivalent, and depending upon the operator's command/request, the downhole device drive circuit **44** will be energized and the downhole device **41** actuated (i.e., opens, closes, partially opens or closes) or data may be obtained from various downhole sensors including, but not limited to, a temperature sensor **46**, pressure sensor **47**, fluid sensor **48** and/or downhole device position sensor **49**. This data is then transmitted to the downhole control module **30** and the surface control unit **12**.

If the transmitted address in the command serial stream does not correspond to the stored address in the interface unit **40**, the bi-directional transceiver **42** transmits the command serial stream to the next interface unit **50** downstream. Following this transmission, the transmitter portion of the transceiver **42** is de-energized and the receiver portion is energized. This process continues until the command serial stream reaches the appropriate interface unit containing the identical address as the transmitted address in the command serial stream.

Figure 3 illustrates an alternative embodiment of the present invention. As in the first embodiment, the alternative embodiment includes a production system **10** comprising, in part, a conventional derrick **11**. However, unlike the first embodiment, the alternative embodiment does not require transmission of surface commands since actuation of the downhole device or group of downhole devices is initiated upon the sensing of a preset downhole parameter (e.g., temperature, pressure, flow or change in position of the downhole device) or event.

Preferably, a power supply **12** is located at the surface to generate sufficient power to drive a downhole control unit **40** and at least one downhole device **41**. The power from the supply **12** is transmitted via armored and shielded lines **22** extending downward from the surface **13** into the

wellbore **20** to the downhole control unit **40** and at least one downhole device **41**. However, it is contemplated that power for the power supply can be generated in the wellbore (e.g., by a turbine generator) or supplied by energy storage devices such as batteries (or a combination of one or more power sources).

Figure 4 illustrates a block diagram of the downhole control unit **40**, comprising a sensor device **46** and a drive circuit **44**. As mentioned above, the downhole control unit **40** operates autonomously by sensing a preset downhole parameter, (i.e., temperature, pressure, flow, position or other area of interest) and actuating the downhole device **41**. For example, in controlling flow through a valve which is prone to heat up or cool down due to pressure differences on either side of the valve, a silicone diode temperature switch or a bi-metal thermostat may be used as the sensing device **46**. Upon sensing a preset temperature, the sensor device **46** switches from an open state to a closed state permitting power from lines **24** to reach the drive circuit **44** and activation (e.g., opening, closing, partially opening or partially closing) of at least one downhole device **41** (or multiple downhole devices) based upon the downhole parameter or event.

The foregoing description is directed to particular embodiments of the present invention for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that

many modifications and changes to the embodiment set forth are possible without departing from the scope and the spirit of the invention. It is intended that the following claims be interpreted to embrace all such modifications and changes.

CLAIMS

1. A system for selective control of at least one downhole device among a plurality of downhole devices, comprising:
   (a) a surface control unit for transmitting a command signal and an activation voltage to a selected downhole device among a plurality of downhole devices;
   (b) a downhole control module electrically responsive to said surface control unit for receiving, interpreting and reformatting said command signal from said surface control unit said control module transmitting said reformatted command signal and said activation voltage to at least said selected downhole device; and,
   (c) an interface unit electrically coupled to the selected downhole device for receiving said reformatted command signal, energizing the selected downhole device and transmitting downhole data to said downhole control module.

2. A system for selective control of at least one downhole device from among a plurality of downhole devices, said system comprising:
   (a) a surface power source for generating an activation voltage for the at least one downhole device; and,
   (b) a control unit for sensing at least one downhole condition parameter; said control

unit electrically coupled to the one downhole device for activating the one downhole device responsive to a predetermined value of said downhole condition parameter.

3. A method of controlling at least one downhole device, comprising:

(a) transmitting a command signal and activation voltage from a surface control unit;

(b) receiving said command signal and said activation voltage by a downhole control module;

(c) interpreting said command signal by said downhole control module;

(d) reformatting said command signal by said downhole control module;

(e) transmitting said reformatted command signal and said activation voltage to at least one predetermined downhole device among a plurality of downhole devices;

(f) receiving said reformatted command signal at an interface unit electrically coupled to said predetermined downhole device;

(g) actuating the predetermined downhole device in response to said reformatted command; and

(h) transmitting downhole data from said interface unit to said downhole control module and to said surface control unit.

Application No: GB 0201644.2 14 **Examiner:** Matthew Perkins
Claims searched: 1 and 3 **Date of search:** 27 May 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): E1F FKF, FKG, FLM

Int Cl (Ed.7): E21B

Other: Online: WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2207161 A (OTIS) See pages 7 to 9	1 & 3

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.